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CONTROL ID: 1816001

TITLE: Stress-dependent voltage offsets from polymer insulators used in rock mechanics and material testing

ABSTRACT BODY: Dielectric insulators are used in a variety of laboratory settings when performing experiments in rock mechanics, petrology, and electromagnetic studies of rocks in the fields of geophysics, material science, and civil engineering. These components may be used to electrically isolate geological samples from the experimental equipment, to perform a mechanical compliance function between brittle samples and the loading equipment, to match ultrasonic transducers, or perform other functions. In many experimental configurations the insulators bear the full brunt of force applied to the sample but do not need to withstand high voltages, therefore the insulators are often thin sheets of mechanically tough polymers. From an instrument perspective, transduction from various types of mechanical perturbation has been qualitatively compared for a number of polymers [1, 2] and these error sources are readily apparent during high-impedance measurements if not mitigated. However even when following best practices, a force-dependent voltage signal still remains and its behavior is explored in this presentation. In this experiment two thin sheets (0.25 mm) of high-density polyethylene (HDPE) were set up in a stack, held alternately between three aluminum bars; this stack was placed on the platen of a 60T capacity hydraulic testing machine. The surface area, A, over which the force is applied to the PE sheets in this sandwich is roughly 40 square cm, each sheet forming a parallel-plate capacitor having roughly 320 pF [3], assuming the relative dielectric permittivity of PE is ~2.3. The outer two aluminum bars were connected to the LO input of the electrometer and the central aluminum bar was connected to the HI input of a Keithley model 617 electrometer. Once the stack is mechanically well-seated with no air gaps, the voltage offset is observed to be a linear function of the baseline voltage for a given change in applied force. For a periodically applied force of 66.7 kN the voltage offsets were measured as a function of initial voltage, and these data were fit with a linear function that was constrained to pass through the origin. The best fit solution had a correlation coefficient of R = 0.85 and a slope of approximately –0.0228 volts/volt. The voltage offset when normalized is demonstrated to be constant –2.28 % for both positive and negative polarities over nearly 3 orders of baseline voltage magnitude. From this, the voltage-force coefficient is derived to be –0.34 ppm/N. This correlates well to a first-order parallel plate capacitor model that assumes constant area, and small deformation such that the polymer may be mechanically modeled by a spring that obeys Hooke's law. This simple model predicts that the coefficient of proportionality is a function of Young's modulus E = 0.8 GPa and surface area of the insulator, theoretically –1/EA = –0.31 ppm/N. The outcome of this work is an improved insulator made from ultra-high molecular weight (UHMW) polyethylene and other approaches toward the minimization of and compensation for these experimental artifacts.

References:
[1] Keithley Instruments, Low level measurements handbook, "Choosing the best insulator," 2-11 (2004).
[2] Ibid., 2-26.
[3] A. Skumiel, "How to transform mechanical work into electrical energy using a capacitor," European Journal of Physics 32, 625-630 (2011).

CURRENT SECTION/FOCUS GROUP: Natural Hazards (NH)

CURRENT SESSION: NH014. Interdisciplinary Collaborations and Progress in Earthquake Forecasting

INDEX TERMS: 0619 ELECTROMAGNETICS Electromagnetic theory, 0694 ELECTROMAGNETICS Instruments and techniques, 7223 SEISMOLOGY Earthquake interaction, forecasting, and prediction , 8194 TECTONOPHYSICS Instruments and techniques.

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